Thursday afternoon

ANALYSIS OF THE SUBJECT-MACHINE RELATIONSHIP

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Overview

An apparent phenomenon which defies the theory of probability occurs when Subject 2 plays this experimental game. He significantly exceeds his probability of success, .25, by scoring over .29. The question that this report addresses is: Is there a statistical or logical reason why he did so well? The methodology used to attack this problem and the resulting conclusions are summarized below. This summary can also serve as an outline to this detailed report.

I. Statistical Analysis of the Machine Experimental Data

Pre-experiment data analysis discovered a non-random characteristic through the examination of forward-backward state transitions (i.e., Red-Blue, Blue-Red). However, the coefficient of correlation between the forward and backward states of .58 for the experimental data, .49 for Machine 1 data and .48 for Machine 2 data were considered low enough that this approach was dropped. Pre-experiment state transitions had a coefficient of correlation of .93.

The experimental data randomness analysis consisted of examining the distribution of color totals and the distribution of each color taken over various combinations and permutations of the data. No evidence of non-randomness was discovered.

II. Analysis of the Subjects' Data Responses

The subject's responses were analyzed with the emphasis on the discovery of his strategy or the unveiling of a trend which would give him a statistical advantage. The possibilities investigated produces no solid reason <u>how</u> he was able to be so successful. However, in one case there is a strong indication <u>why</u> he was able to succeed. It appears that he was learning the states of Machine 2. The details of this are in

the remainder of the report.

Miscellaneous

The report contains a section entitled "Miscellaneous" for the purpose of displaying detailed data which wasn't directly required by the above more general analysis. Details such as how many successful choices in the color red during the 50th trial were there, or what was the relationship of the number of passes to the number of successes.

The terminology used is as follows: the term "trial" refers to the string of machine states and corresponding choices from the time the subject begins until he makes 25 non-passing choices. A sample is a machine state and/or subject choice (including passes). There are (25 + # passes/trial) samples in each trial.

I. Statistical Analysis of the Machine Experimental Data

SG1I

Forward-backward State Transition Analysis

In a previous memorandum (Memo ORD 2240-75, 12 June 1975 to [redacted] the question of randomness with the emphasis on state transitions as an indication of non-randomness was addressed. The data used in the investigation consisted of pre-experiment trials. The purpose of this section is to do a similar investigation using the actual data which occurred during S2's experiment.

Table 1 presents all possible transition frequencies. All transitions should have equal probability.

	YELLOW	GREEN	BLUE	RED
YELLOW	204	199	199	216
GREEN	192	218	222	207
BLUE	211	206	228	222
RED	209	206	223	221

Restructuring into a two-by-six table as in Ref 1 produces:

	Y/G	Y/B	Y/R	G/B	G/R	B/R
FORWARD	199	199	216	222	207	222
BACKWARD	192	211	209	206	206	223

The conclusion based on pre-experimental data was that these state-pairs show a very strong relationship between forward and backward transition frequencies (coefficient of correlation =.93). However, computing the coefficient of correlation, p_{s2} actual data = .58, it becomes apparent that the degree of dependence is slightly reduced. Therefore the dependence of forward to backward states can no longer be considered as a strong indicator of non-randomness.

The data used in the above discussion consisted of trials from both machine 1 and machine 2. Since non-randomness, made apparent by the state transitions, clearly existed for pre-experimental data, the investigation of the experimental data continued to include a search for this trend in the individual machines. The transitions (including identity) are as follows:

Machine 1

	YELLOW	GREEN	BLUE	RED
YELLOW	96	79	88	92
GREEN	85	87	86	88
BLUE	85	82	90	87
RED	91	91	83	92

Machine 2

	YELLOW	GREEN	BLUE	RED
YELLOW	108	120	111	124
GREEN	107	131	136	119
BLUE	126	124	138	135
RED	118	115	140	129

Computing the two coefficients of correlation,

$$\rho'_{\substack{\text{machine 1} \\ \text{s2 data}}} = .4934$$

and

$$\rho'_{\substack{\text{machine 2} \\ \text{s2 data}}} = .4838$$

it is obvious that the forward and backward transitions are even less dependent than in the combined case. Thus ended the search for non-randomness through state transition.

As a by-product the following table is produced for general information.

	BOTH MACHINES		MACHINE 1		MACHINE 2	
	MEAN	SD	MEAN	SD	MEAN	SD
FORWARD	210.8	10.7	86.6	4.27	124	9.74
BACKWARD	207.8	9.00	86.2	3.92	121	11.25
TOTAL DATA POINTS	3483		1446		2037	
COEFF OF COV	.5843		.4934		.4838	

3191
2702
3650

Experimental Data Randomness Analysis

The machine data used during the S2 experiment has been combined, summarized and/or permuted in an attempt to establish evidence of randomness or non-randomness. If an obvious indication of non-randomness would have evolved this task would be simplified because it would have become a closed form problem (i.e., the solution would be - the data has non-random characteristics). However, what has resulted is that various forms of the data have been examined with all indicating that the data is random.

Tables, plots and commentary are presented in this section to demonstrate randomness and in some cases just to provide general information concerning the machines data.

The distribution of the colors collectively and for each machine is as follows:

	Yellow	Green	Blue	Red	Total	Mean
Machine 1	365	353	356	372	1446	361.5
Machine 2	475	505	538	519	2037	509.25
TOTAL	840	858	891	891	3483	870.75

Machine 1 was not used in as many trials as machine 2 (44 trials to 56 for machine 2), thus the difference in totals. The standard deviation of binomial distribution with n=3483 and p=1/4 is 25.56 which would imply that each separate number is reasonably close to the mean.

Accepting the distribution of the totals consider the distribution of the colors throughout the experiment. The popluations used for this investigation consisted of the first 25 samples of each trial (100 trials total). This population is acceptable since the distribution of its totals was reasonable and since the performance of S2 was approximately the same (success-29.61%) for this subset.

The following three approaches comprise the strategy used to attack the question of color distribution.

1. Each trial (abbreviated to 25 samples) as analyzed separate interval. Obviously this will indicate any bias within each trial.
2. The data (2500 samples) is divided into intervals of five samples each. This will indicate unusual repetitions either within the interval or interval-by-interval.
3. The data is reformatted into 25 intervals of 100 samples, where the nth interval consists of the nth sample in each trial.

The results of approach 1 is shown in Figures 1.1.a, 1.1.b, 1.1.c, and 1.1.d.

The binomial distribution for this strategy (n=25 p=1/4) is mean 6.25 and the variance 4.69. The plots indicate randomness throughout the 100 trials.

The results of approach 2 are similar to approach 1 and are shown in the four tables in Figure 1.2. The plots indicated randomness but are not shown because of monotomy. The binomial distribution mean is 1.25 and the variance .94.

The binomial distribution mean and variance for approach 3 is 25 and 18.75 respectively (Figure 1.3). A plot of the data (Figure 1.4) for the "RED" case because of the concern for the higher variance and ranges. The 13th sample seems to have an unusually high frequency of "RED" (44%). However in general this investigation has not produced a significant non-random characteristic.

sample size	100
maximum	12
minimum	3
range	9
mean	6.23
variance	4.239494949
standard deviation	2.059003387
mean deviation	1.6314
median	6
mode	6

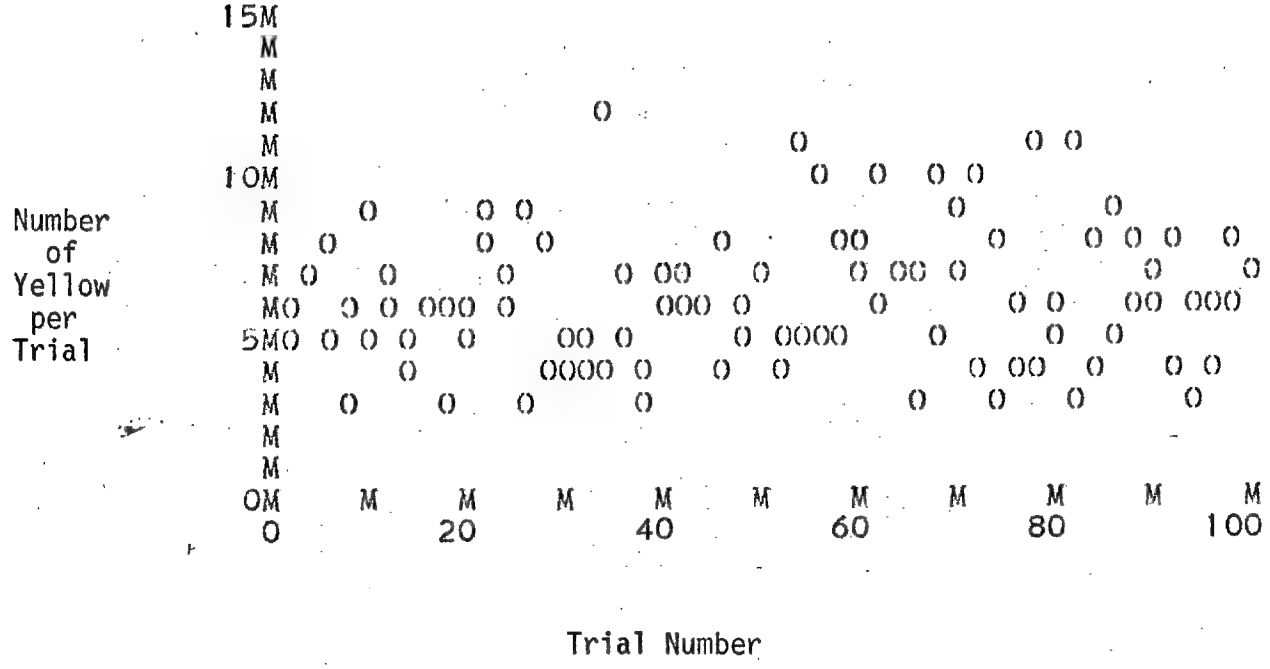


Figure 1.1.a Distribution of Machine Yellows Over Trials

sample size	100
maximum	12
minimum	0
range	12
mean	6.13
variance	5.851616162
standard deviation	2.419011402
mean deviation	1.9404
median	6
mode	5 7

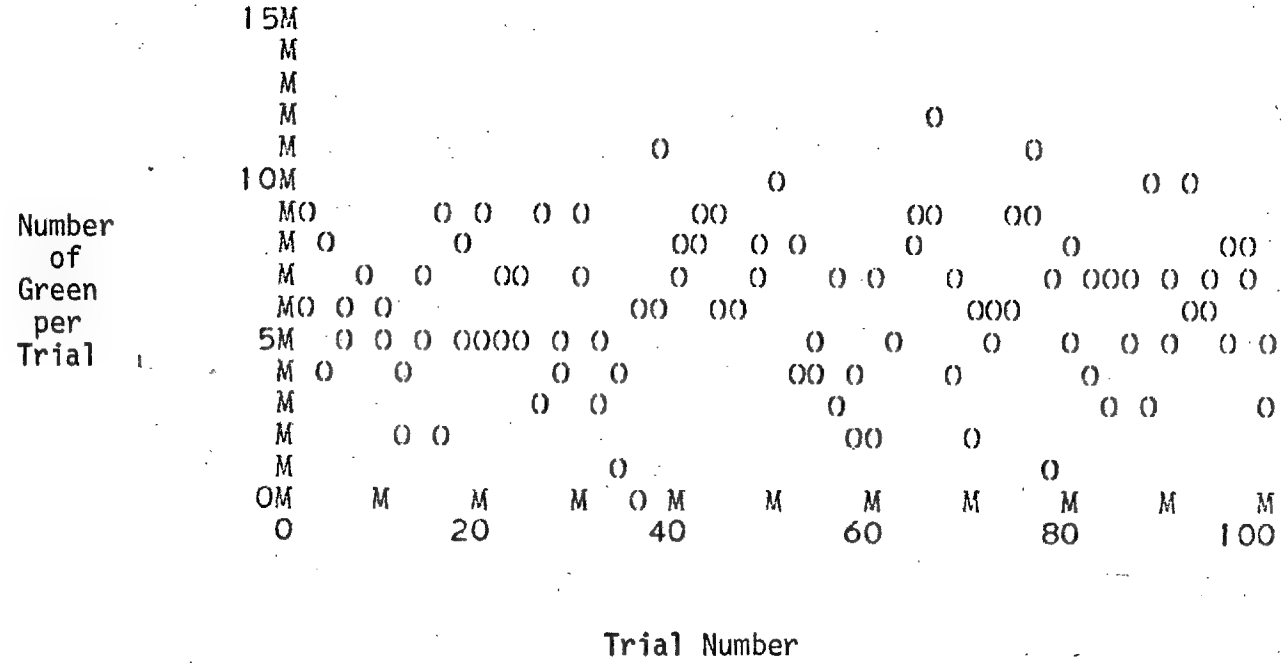


Figure 1.1.b Distribution of Machine Greens Over Trials

sample size	100
maximum	11
minimum	1
range	10
mean	6.21
variance	5.218080808
standard deviation	2.284311889
mean deviation	1.8194
median	6
mode	6

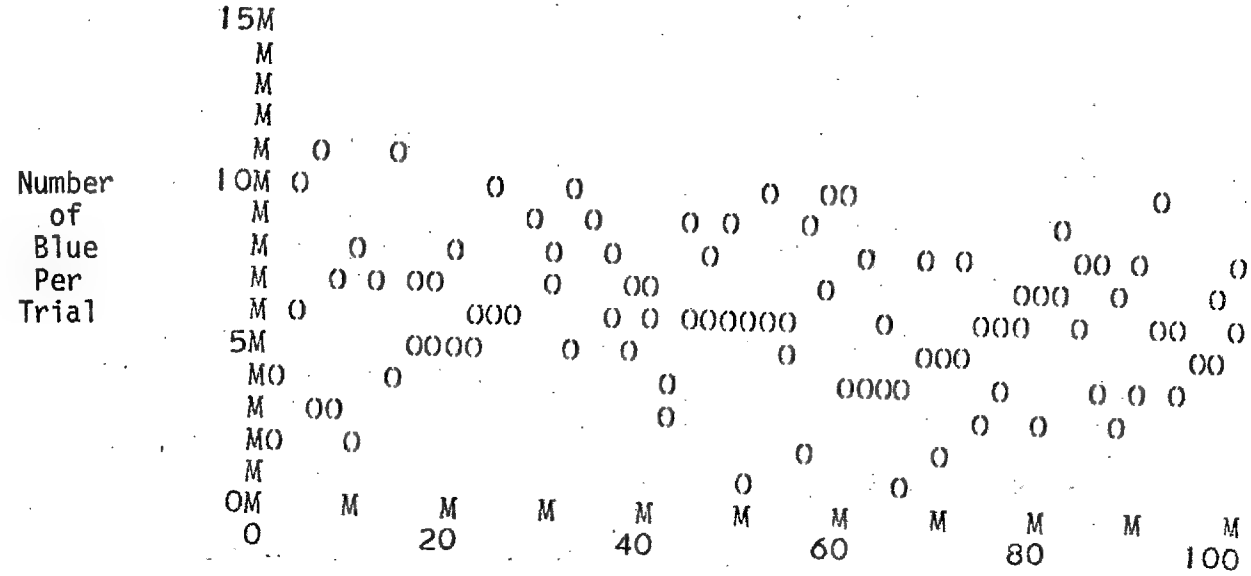


Figure 1. The Distribution of Blue Over Trials

sample size	100
maximum	12
minimum	1
range	11
mean	6.43
variance	4.631414141
standard deviation	2.152072058
mean deviation	1.7158
median	6
mode	6

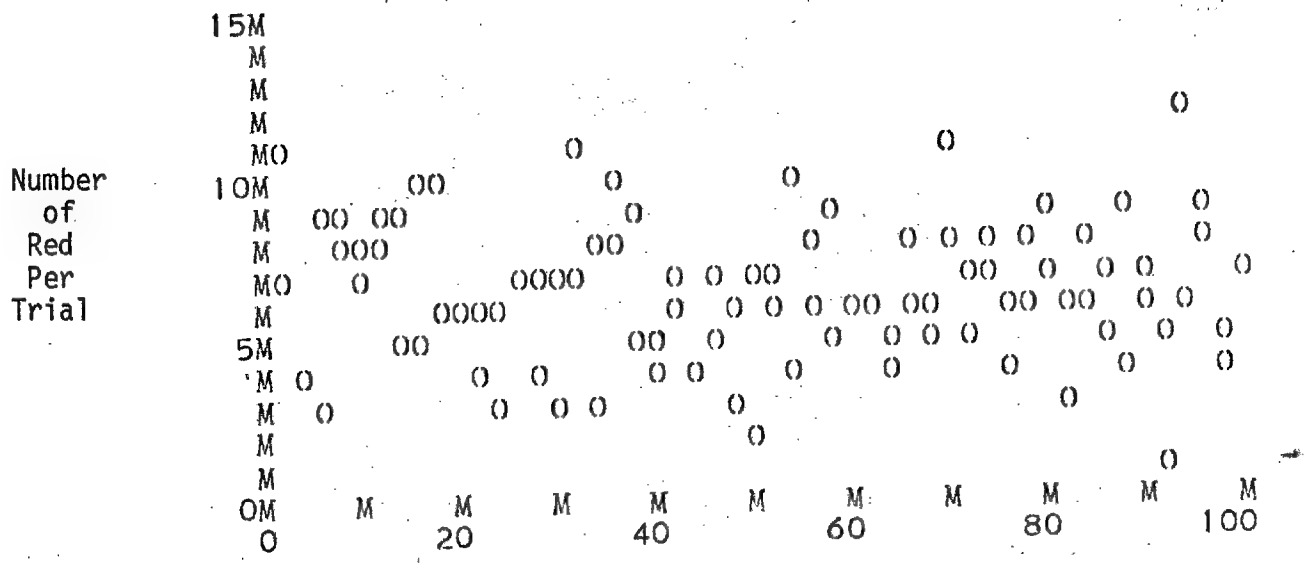


Figure 1.1.d Distribution of Machine Reds Over Trials

Distribution of

sample size	500
maximum	5
minimum	0
range	5
mean	1.246
variance	0.9594028056
standard deviation	0.9794910952
mean deviation	0.784848
median	1
mode	1

Distribution of Green

sample size	500
maximum	5
minimum	0
range	5
mean	1.226
variance	0.9969178357
standard deviation	0.9984577285
mean deviation	0.804512
median	1
mode	1

Distribution of Blue
dstat grp;<3;

sample size	500
maximum	4
minimum	0
range	4
mean	1.242
variance	0.9573507014
standard deviation	0.9784429985
mean deviation	0.792792
median	1
mode	1

Distribution of Red

sample size	500
maximum	5
minimum	0
range	5
mean	1.286
variance	1.026256513
standard deviation	1.013043194
mean deviation	0.823216
median	1
mode	1

Figure 1.2 Distribution of Marbles in Urn When Samples are Taken Five at a Time

Yellow Distribution

sample size	25
maximum	31
minimum	19
range	12
mean	24.92
variance	10.57666667
standard deviation	3.252178757
mean deviation	2.6304
median	24
mode	24

Green Distribution

sample size	25
maximum	35
minimum	15
range	20
mean	24.52
variance	24.59333333
standard deviation	4.959166597
mean deviation	3.9392
median	25
mode	22 25

Blue Distribution

sample size	25
maximum	34
minimum	19
range	15
mean	24.84
variance	14.47333333
standard deviation	3.804383437
mean deviation	2.9664
median	25
mode	26

Red Distribution

sample size	25
maximum	44
minimum	16
range	28
mean	25.72
variance	26.71
standard deviation	5.168171824
mean deviation	3.3664
median	25
mode	25

Figure 1.3 Distribution of Machine Colors When Samples are Taken 100 at a Time (One From Each Trial)

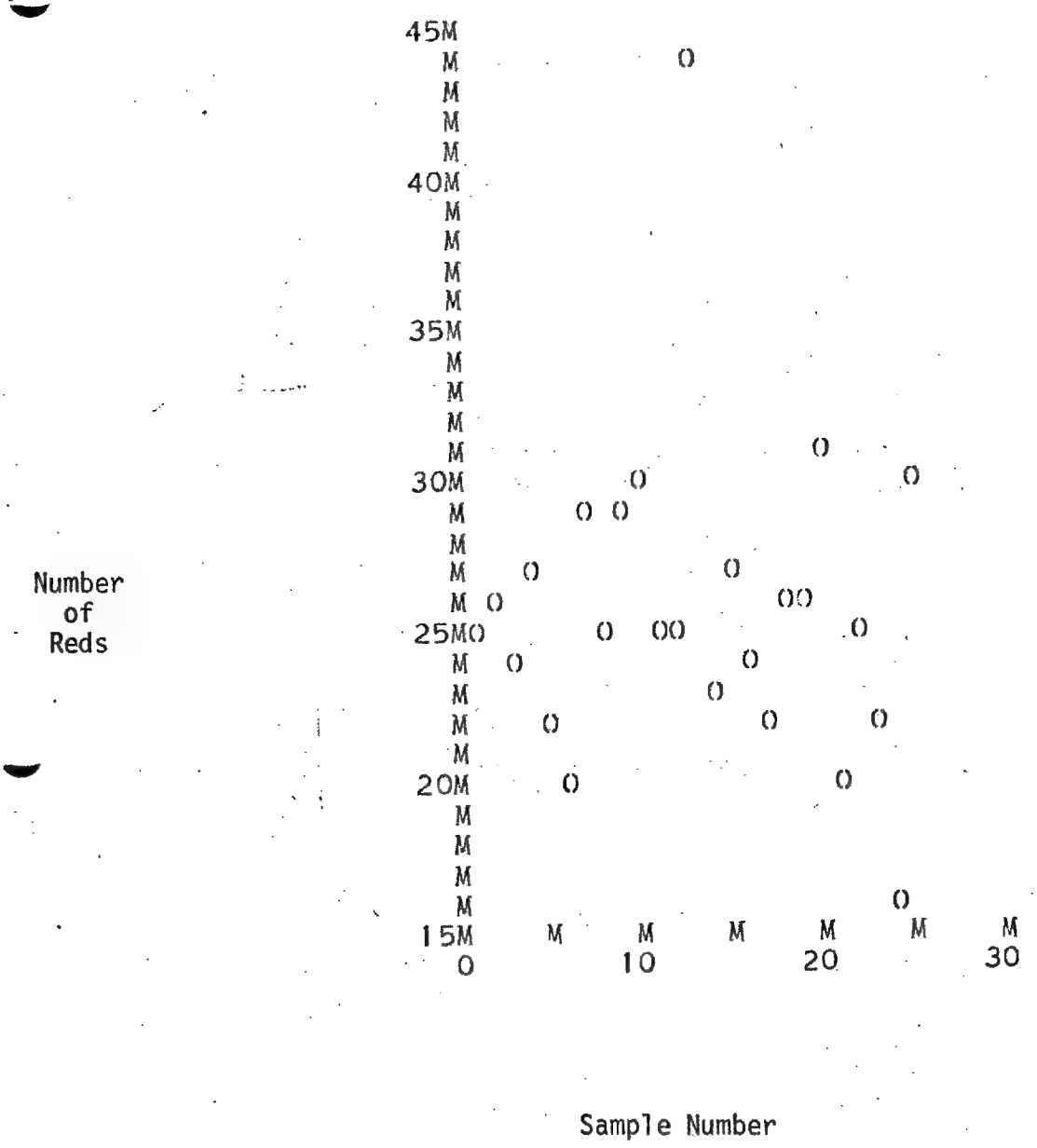


Figure 1.4 Distribution of Machine "Reds" when the Samples are taken 100 at a time (one from each trial)

Approach 1 has been repeated for Machine 1 and Machine 2 separately to check for abnormalities. The binomial distribution mean and variance are as follows:

	Trials	Mean	Variance
Machine 1	44	11	8.25
Machine 2	56	14	10.5

	Machine 1	Machine 2
Yellow		
sample size	25	25
maximum	16	19
minimum	7	7
range	9	12
mean	11.4	13.52
variance	7.75	7.51
standard deviation	2.783882181	2.740437921
mean deviation	2.224	2.176
median	12	14
mode	12	15
Green		
sample size	25	25
maximum	17	24
minimum	4	8
range	13	16
mean	10.68	13.84
variance	9.726666667	12.72333333
standard deviation	3.118760438	3.56697818
mean deviation	2.3584	2.7808
median	11	13
mode	11	13
Blue		
sample size	25	25
maximum	15	25
minimum	3	10
range	12	15
mean	10.32	14.12
variance	7.726666667	8.943333333
standard deviation	2.779688232	2.990540642
mean deviation	2.3072	1.984
median	11	14
mode	8 12	15
Red		
sample size	25	25
maximum	19	21
minimum	4	11
range	15	10
mean	11.6	14.52
variance	10.5	10.01
standard deviation	3.240370349	3.163858404
mean deviation	2.4	2.6624
median	12	13
mode	12	11 13

Figure 1. Machine color distribution for Machine 1 and Machine 2 on a Trial To Trial Basis (14)

Best Strategy

Based on the above analysis what is the best strategy to pursue? No good strategy is available based on the randomness of the data. The best possible strategy based on the above transition matrices is:

1. If the subject can't distinguish between machine then press blue when blue appears, else pass.
2. If the subject can distinguish them on Machine 1, press yellow when yellow occurs, and on Machine 2 press blue when red occurs.

For all its worth, of the existing data the following success would result - 26%, 26%, and 27%.

Analysis of S2 Data Responses

The attempt here is to discover a reason for S2's success at responding. The investigation was unable to give a definitive reason for his success. Although no strategies were uncovered there was in one case a indication that the subject was learning.

Two major approaches have been taken in this investigation. They are as follows:

1. Strategy of S2 - Was there any trends in the way he guessed? Did he respond based on the previous state of the machine?
2. Hit analysis - Did the subjects' hits (correct choices) increase within a run; did it increase from run to run (i.e., was he learning?)

Strategy of S2

For general information and future reference the first figure (Figure 2.1) presented is the actual choices. One item of curiosity from this is that when he passes, he tends to do it in strings. This characteristic of course wasn't pursued because of its insignificance to this report; however, observations like that are pointed out throughout the report as possible importance to those in the field.

Total Color Choices

The distribution of S2's color choice totals are shown below.

```
021023201021300302030033O
020312130303033000010233Z
300310303031203210322212З
023331002032013030002031З
303003001030303131303010З
330303130303000320210310З
032303030302030103203033O
032030303030210303030130З
030303202230301031302102O
301010310301330301302301З
031302331330310201310323Ι
021031031031033203103023O
303020310303013013030302З
303032301303020301033030З
303003030230313031303130O
302313030210231301013020З
303070307300103077230770731377030773
320301303077307070130303723770373
030230107370377373017303071777072073Ο
021303077730702302303070723730703
037010377773210337003713070773010З1
077737773077731707737703723310327307303037З
373031377773073277307707307707073007077773203
307370307302130313313777073023777377770
030317001201203130277232З103
013132020312031077307173077777203Ι
303730303777303013073077703303777777З070
312170330301300377777713000120О3
002730770377277777310777377777737777777731321330130703
317377777777777771707107777777301377770737031327777770307777370Ι3
377770777701777777770307373177777303031031031020
377172707777013071737177777377777777777020303170132Ο1
037777777777377010377777707770777777777730131313030230320
002307130130777777777777130130232013О3
077777701010203010230703730270730777777713
307137770370777037777732310777777777777777703130777777777777777737037037Ι1
302077771303703130313021037013777777777777770
310373210130131023103701077З1
313130231301320130237301777О3
130373737301301320777773777777777707313021071
137310373731730217727317713177777777703733170
132370130770723131031277737131737773Ι3
313777777777773777033131021371777777170777317271207Ι3
012370737731777317372017203070721701З0
073373113701310701077201377032770070
321317032331303203723032123
137370710303107720311307100323773
103077102373713073072302338З03730
203033023131330221212133Ι
230777012732120003033331303ОО
```

Figure 2.1 Subject 2 Color Choices for First Fifty Trials (0-yellow, 1-green, 2-blue, 3-red, 7-pass)

32303130120213707712321723030
03113730117310203777777777037737301733307 0
20703123070231703030330133703
30170102031730730300330313713
0100777737370730377717377727337731077077713077737377 3
20707370731777370077037370002731777070777770737777773777773
01730330320370330327013703013
30371703320730307377301302373720 3
03737373033730321732333771737337073 71
23707377313033333703773773707173777377373270
13107303737730103333370737313707700
33373707730730373333130373370707707 33
03303773770333733777707777732777730102733733 3
03030372000037737337770773773303033 2
33032133270323233130121330
10701101301101313030230123
30070330072373003037177713777703300 2
03133737370300032000300010 03
30233213100000137130370303777 0
77201771007703072370313731013777377177777303
33717101771137130021733373303073 3
30717373717077130117303707301373370071
03303203020071027107377121270703
03231327320373023770331110077700
33173707371071317331331730117207073
27131310732703327773117713032330 3
30003733000330037103030713 30
30127001333301307773707737330337777077 0
03037030370737323113707107320017 73
37733070072000770300373130003002
13200200030030377030073172337 0
30707207020773307033030303777377737737707 3
07077730703700377777707731707330307307077770737373
00707737377003073730777777707377777737773770300077773333
13010371320107173010027200737 23
31013103170013000017300730 20
03777720070773100770707373007200730700700
30300007100000232113002002
30313013013201302310330 03
23012031301203103113031 20
30130231031737130730323001 31
30130130132013021013023 03
13023103230371327303103013 0
30103103107732303130730213 31
31031303173770137300133003377771 3
31301030310330307377070037717003
02313033201370013723020133 0
02173731031013037000730277773103 73
13707310710370237313271033107370 3
33130030170730107070037107370071 3

Figure 2.1 (Continued) S2 Color Choices for Last 50 Trials

	Yellow	Green	Blue	Red
Total Times Chosen	881	411	237	971
% of Total	35%	16.5%	9.5%	39%

The first inclination is to try and determine how his strategy of choosing so many yellows and reds benefitted him. Examine the following table:

	Yellow	Green	Blue	Red
Total Number of Hits	255	127	60 (was 50)	292
% of Total Hits	35%	17%	8%	40%
% of Success in Color (Hits - Correct Choices)	29%	31%	25%	30%

As can be seen his results with blue are significantly lower than the others. However, assuming the probability of success to be .25 and using the binomial distribution the expected value =69 and the standard deviation = 7. The inference from this is that the 60 Blue hits are not a statistical abnormality. However, it is curious that he did so much worse on his lowest preference.

State Transition Color Choice

This investigation consists of examining the states of the machine verses the choice on the next sample of the subject (i.e., if the machine shows "red" does the subject consistently choose one color on the next turn). Consider the following table:

	MACH \ SUBS (Machine)	Yellow	Green	Blue	Red	Pass	% Pass
SUBJECT	Yellow	106	119	69	314	210	26%
	Green	177	25	69	316	252	30%
	Blue	241	99	27	198	302	35%
	Red	322	157	65	97	218	25%

r = .30

The subject obviously avoids repeats (i.e., he assumes the machine won't repeat a color) which, based on the machine data analysis, isn't a strategy which would give him a statistical advantage. Previous analysis showed that identity transitions are approximately equally probable as nonidentity. Notice also that he passes 35% of the time after seeing a blue.

The same state transitions are shown below separated by machine.

		Yellow	Green	Blue	Red	Pass
MACHINE 1	Yellow	48	49	25	150	83
	Green	62	13	35	153	83
	Blue	105	36	10	78	115
	Red	133	72	30	58	64
			≠ .94 ↕			
MACHINE 2	Yellow	58	70	44	164	127
	Green	115	12	34	163	169
	Blue	136	63	17	120	187
	Red	189	85	35	39	154

The negative state transition (i.e., relationship of the subject color choice to the machine state on the next sample) is considered too bizarre of a concept to be presented in this section. Results of that investigation is found in the section entitled "miscellaneous"

Hit Analysis

This section is significantly more important than the randomization analysis of the machine data. The reason is that if he is not learning from the machine or he is not taking advantage of biases then the discovery of such non-randomness is of little value to the overall analysis.

Learning from Trial to Trial

The question of whether the subject learned from trial to trial can best be answered by examining the following three plots. The first is the number of hits vs. the trial number, the second is a frequency distribution of the number of trials vs. number of hits, the third is the accumulated probability vs. the trial number.

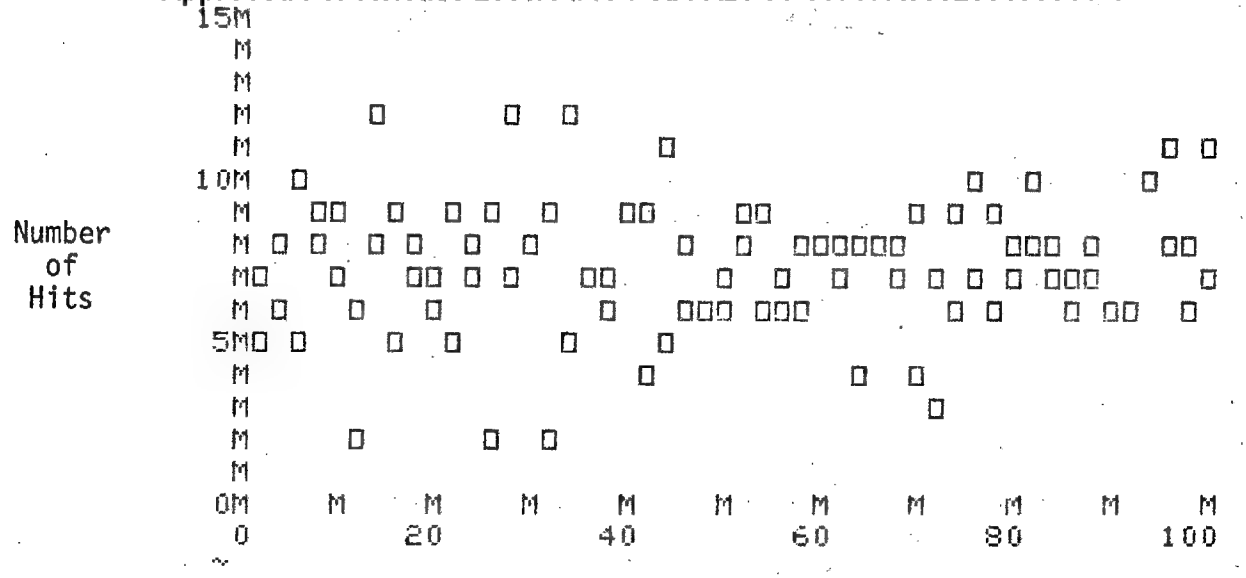


Figure 2.2 Plot of number of hits/trial

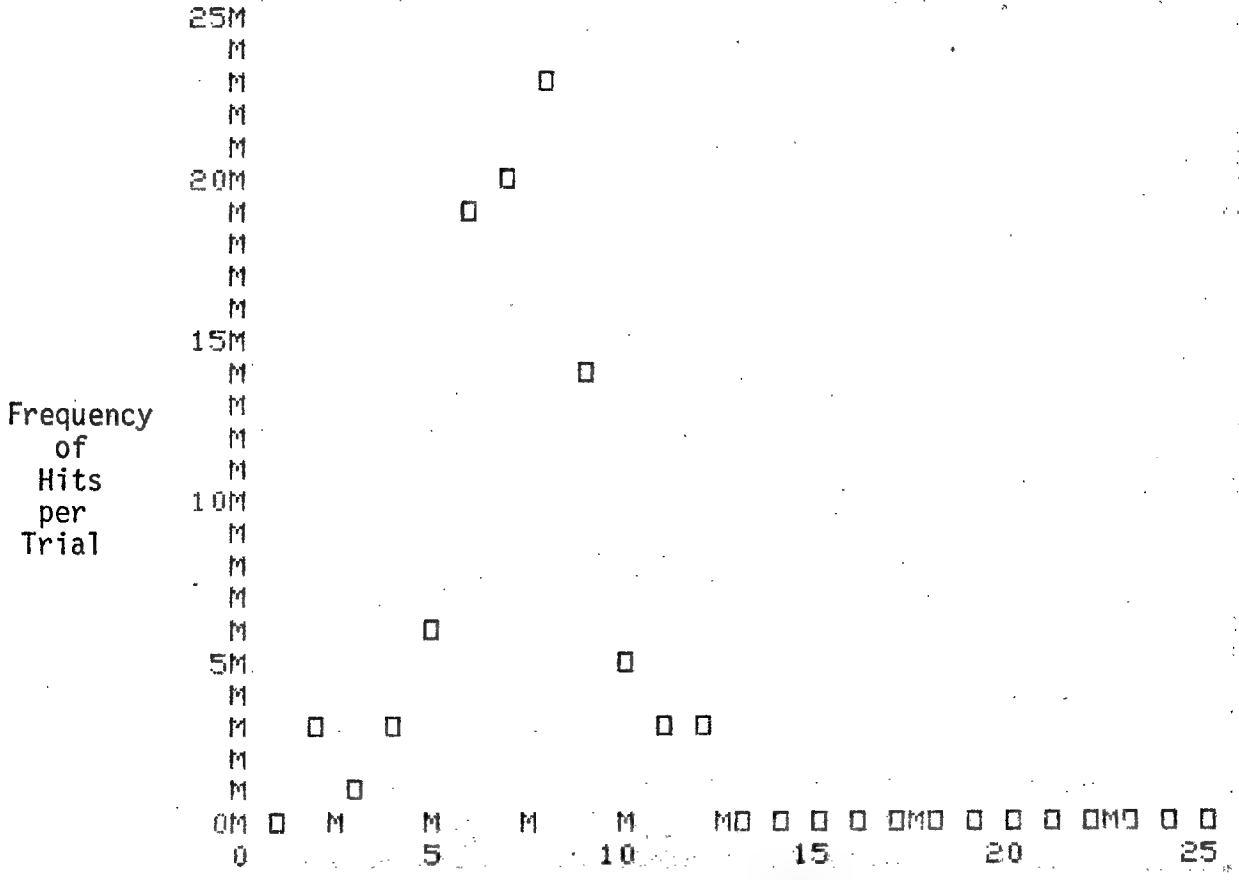


Figure 2.3 Frequency plot of Number of Hits

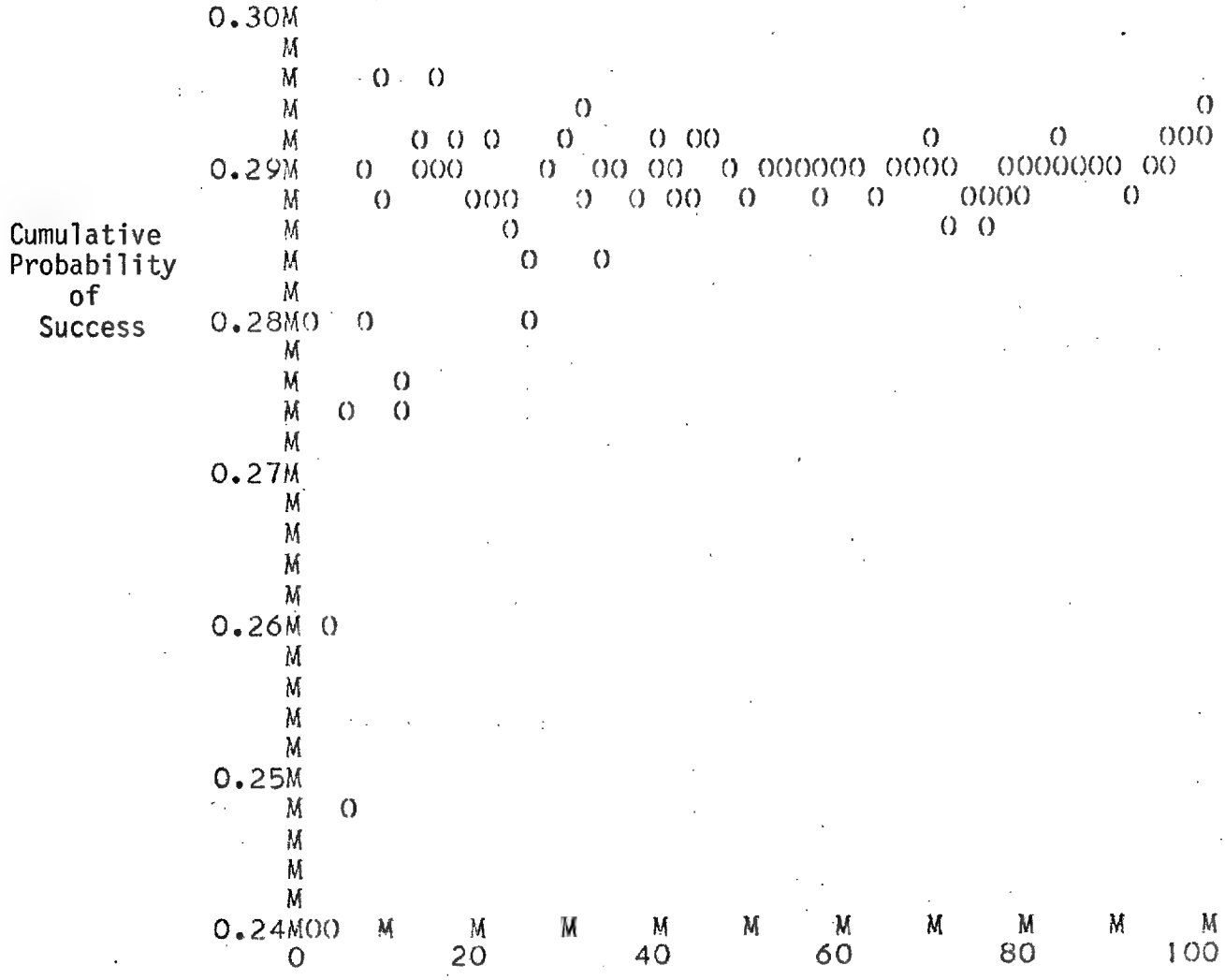


Figure 2.4 Cumulative Success Ratio of Subject (both machines used)

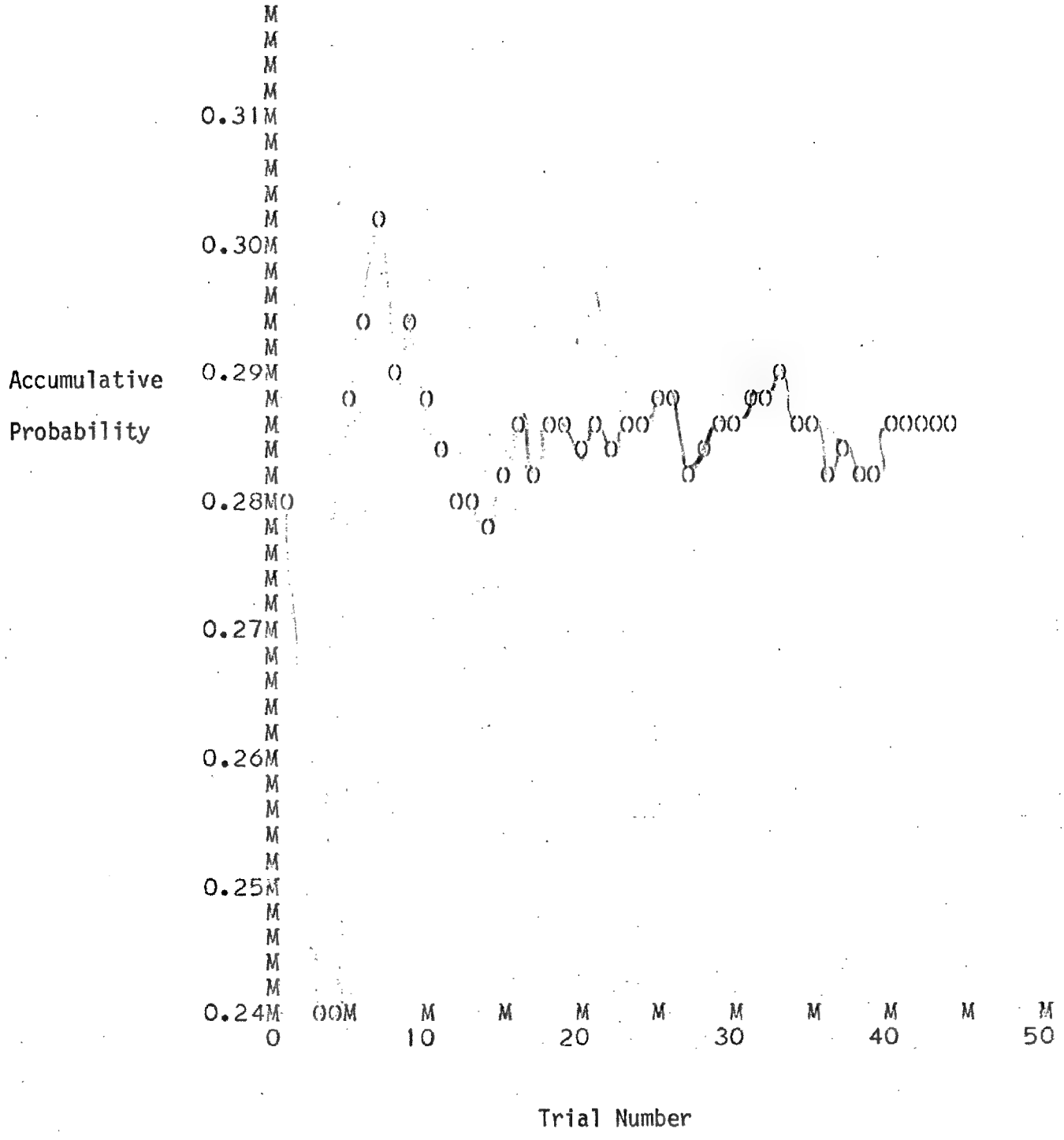
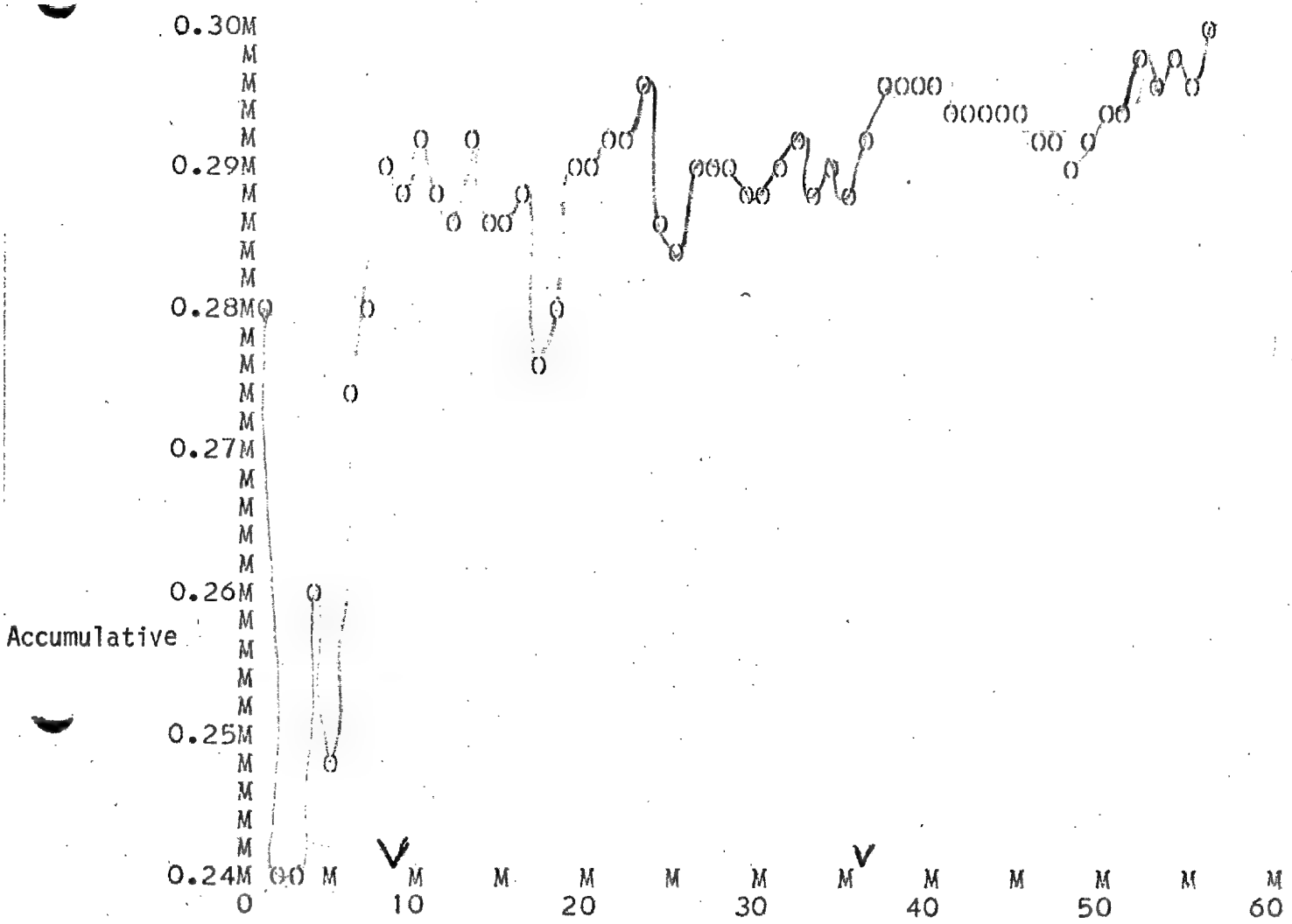


Figure 2.5 Accumulative Probability of Success on Machine 1



Note: V - Points at which he switches machines

Figure 2.6 Accumulative Probability of Success on Machine 2

The first plot (Figure 2.2) demonstrates the randomness of the number of hits while the second plot (Figure 2.3) demonstrates the frequency distribution takes on a "normal" appearance. The accumulative probability plots, at first glance, indicates that the subject was in a learning mode for the first five trials. A closer examination of the data indicates that this can occur naturally as part of the statistical distribution.

The first three number of hits points are 7, 5, and 6 considering the first 75 points as the population with probability of success = .2936 (the final probability) then the expected value is 22 (using binomial distribution) and the variance is 15.55 (S.D=3.9). As a normal deviation from the mean (i.e., using normal distribution approximation $P(x<18)=.13$.

Although the observed learning can be rationalized as a natural statistical deviation it warranted further investigation. The plots of the accumulative probability of success for machine 1 and machine 2 are presented in Figure 2.5 and Figure 2.6. The plot for machine 1 (Figure 2.5) is a typical sinesodial decreasing amplitude convergent curve. The plot for machine 2 however, is very suspicious in terms of learning. The major peaks of the curve (at approximately trial 10, 23, 40 and 56) are increasing which implies his probability of success is continuing to increase instead of converging on one point. Another interesting point is that the points at which he switches onto machine 2 are 1, 9, and 36.

Also of concern is the sharp upward turn during the last 8 samples. The hits totals for this period, starting at sample 49 is 10, 10, 8 11, 6, 8, 7, and 11 for a total of 71 hits out of a possible 200 for a probability of success of .36. Once again using the binomial distribution and using the probability of success of .29 (the cumulative probability up to the 49th point) the expected mean is 58 and the standard deviation 6.42. Using the

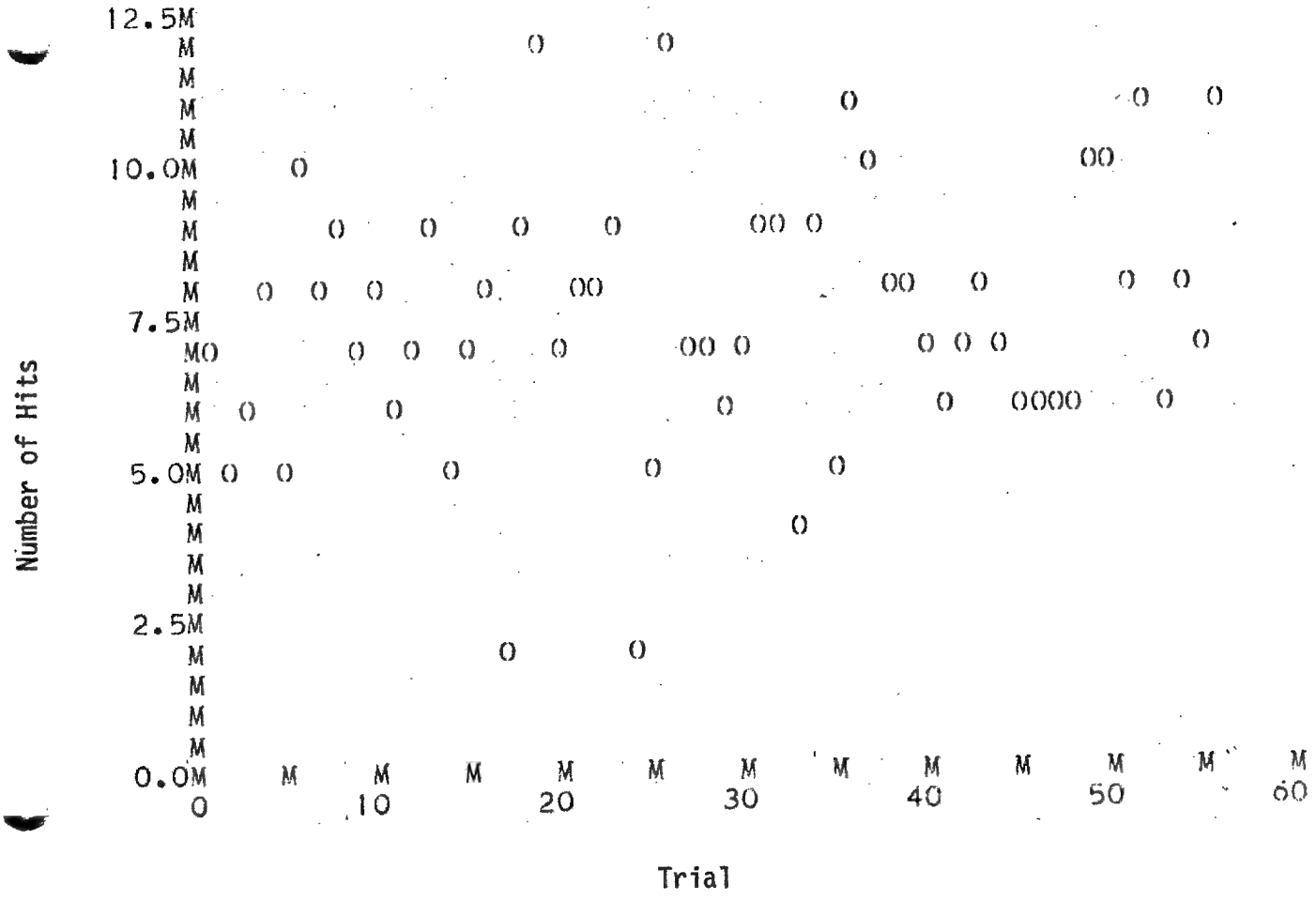


Figure 2.7 Plot of Number of Hits on Machine 1

normal approximation the probability P(X 71)=.02 of such an occurrence is quite low.

Although there are only 56 data points in this population and the apparent abnormalities are statistically possible (with low probability) this investigation concludes that the subject's learning for this case must be flagged as a real possibility. Figure 2.7 (Number of hits on Machine 1) has been added to provide clarity. It appears that the subject just didn't have "low hit" days toward the end.

Learning within a Trial

The question of learning within a trial or run has been investigated by summing the number of hits of the Ith sample for the run. The results are somewhat distorted because of the inequitable distribution of passes. The lower numbered samples have significantly more hits because of this. A plot of the number of hits per sample vs. sample number is shown in Figure 2.7.

Notice that the first sample has a value of 34 hits. This means that everytime he ists down for a new 25 sample trial he hits 34% of the time on his first try. With this in mind along with the rest of the data points, it is obvious that the subject doesn't learn throughout the trial.

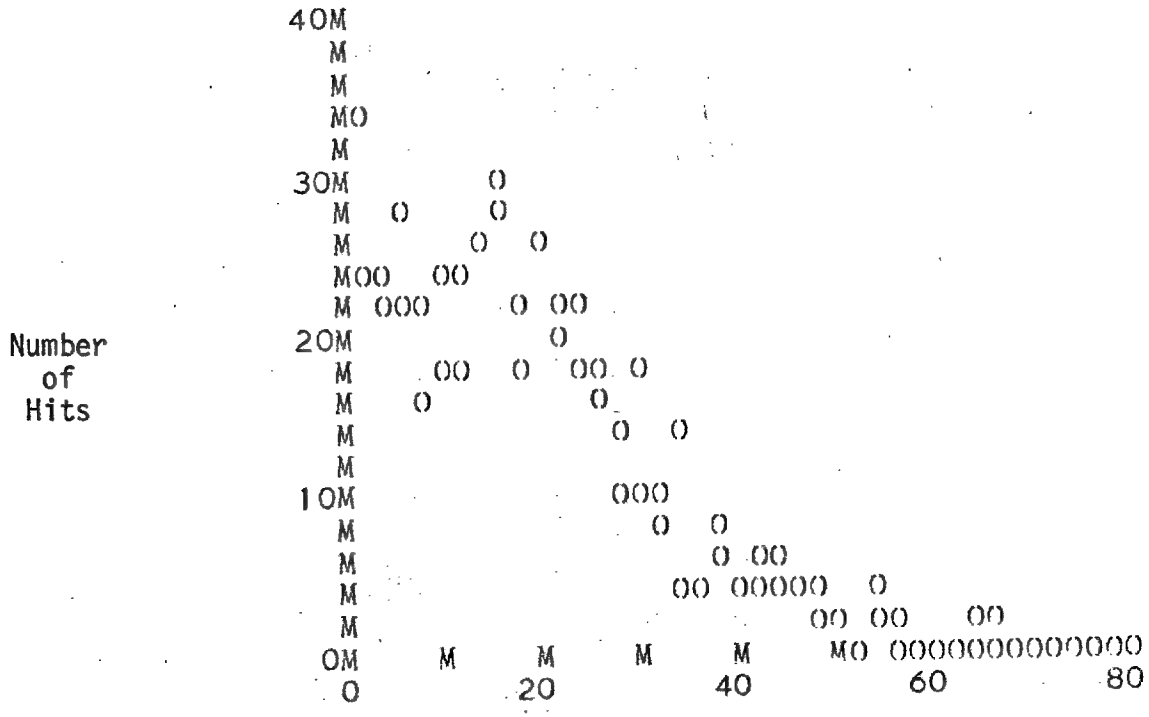


Figure 2.8 Total Number of Hits Within a Trial

Miscellaneous

Numerous arrays of data have been examined for the purpose of obtaining some insight into the data. Some of the data is being printed herein so that the data can be examined more closely if desired.

This first table is presented for use as a quick reference.

Day	Last Trial	Number of Tracks	Machine Used
1	8	8	2
2	16	8	1
3	24	8	2
4	36	12	2
5	44	8	2
6	52	8	1
7	56	4	1
8	64	8	1
9	68	4	1
10	72	4	1
11	76	4	1
12	80	4	1
13	84	4	2
14	88	4	2
15	100	12	2

The following displays are presented below with little commentary.

I. General trial summary (Figure 3.1). Each trial (25 choices) is listed with the following information.

   A. Machine used (1 or 2)

   B. Total number of machine states in each color (i.e., 6 yellow, 6 green ....) for each trial.

   C. Total number of subject choices for each color for each trial.

   D. Total number of hits for each trial.

   E. Total number of passes for each trial.

   F. Breakdown of hits by color.

II. Machine data for machine 1 and machine 2 separately (Figures 3.2, 3.3) Just by examining these displays it may be possible to glean meaningful information. For example, machine 1 was used for the first 8 trials during which the first state of each trial was a yellow or red. If the first sample of each trial is most memorable, perhaps this is responsible for the subject's obvious preference of yellow and red (see Section 2 - Analysis of S2 Data Responses).

III. Plots of the number of passes made.

   A. Number of passes vs. trial number (i.e., trial is 25 or more samples) (Figure 3.4)

   B. Number of passes vs. sample number (Figure 3.5)

trial	mach	mach yell	mach gren	mach blue	mach red	sub yel	sub grn	sub blu	sub red	numb hits	num pas	hit yel	hit grn	hit blu	hit red
1	2	6	6	2	11	11	3	5	6	7	0	3	0	0	4
2	2	5	9	4	7	10	3	4	8	5	0	2	1	0	2
3	2	7	8	6	4	7	4	6	8	6	0	2	2	1	1
4	2	7	4	10	4	10	3	4	8	8	0	4	1	2	1
5	2	5	6	11	3	11	4	0	10	5	0	2	1	0	2
6	2	8	5	3	9	10	3	2	10	10	0	3	1	0	6
7	2	3	7	7	8	11	1	3	10	8	0	2	0	2	4
8	2	6	7	3	9	11	2	2	10	9	0	4	1	0	4
9	1	9	6	2	8	10	3	5	7	7	0	4	0	0	3
10	1	5	5	8	7	9	6	1	9	9	0	3	3	0	3
11	1	6	4	7	8	6	6	3	10	2	0	0	0	0	2
12	1	7	2	7	9	9	5	3	8	6	0	4	0	0	2
13	1	5	7	4	9	10	3	2	10	12	0	3	2	1	6
14	1	4	5	11	5	10	2	2	11	8	0	2	1	2	3
15	1	6	9	5	5	10	3	1	11	9	0	3	2	0	4
16	1	6	2	7	10	8	5	4	8	5	0	2	0	0	3
17	2	10	12	7	7	12	2	1	10	7	11	4	0	0	3
18	2	4	9	9	11	10	2	2	11	8	8	1	1	1	5
19	2	8	9	10	11	11	3	2	9	6	13	3	0	1	2
20	2	7	13	5	8	11	1	4	9	7	8	3	1	1	2
21	2	9	8	9	9	10	5	1	9	9	10	3	2	0	4
22	2	13	12	9	9	8	2	2	13	5	18	0	0	1	4
23	2	9	9	15	12	11	1	2	11	7	20	2	0	1	4
24	2	10	9	11	9	8	3	2	12	8	14	3	2	0	3
25	2	3	11	7	8	8	5	5	7	2	4	1	0	1	0
26	2	10	4	10	10	8	6	4	7	9	9	4	0	2	3
27	2	11	6	15	9	11	1	0	13	12	16	6	1	0	5
28	2	5	6	10	11	10	5	2	8	7	7	2	1	1	3
29	2	7	16	16	14	8	4	3	10	8	28	1	2	1	4
30	2	16	19	18	12	8	6	1	10	8	40	3	3	0	2
31	2	10	10	9	19	10	5	1	9	9	23	2	1	1	5
32	2	12	9	19	12	8	7	3	7	2	27	2	0	0	0
33	2	11	14	20	10	9	4	2	10	5	30	2	1	1	1
34	2	16	4	10	8	9	5	3	8	12	13	5	2	1	4
35	2	9	7	11	15	12	4	3	6	7	17	3	0	2	2
36	2	14	17	19	22	9	4	1	11	7	47	2	1	0	4
37	2	5	16	13	11	9	5	2	9	6	20	0	4	0	2
38	2	5	7	8	9	7	8	2	8	7	4	1	3	0	3
39	2	7	7	9	6	6	6	3	10	9	4	1	3	1	4
40	2	11	13	10	10	7	6	2	10	9	19	2	4	0	3
41	2	10	14	9	12	4	8	2	11	4	20	1	1	0	2
42	2	11	11	7	9	4	7	3	11	9	13	2	3	0	4
43	2	15	13	14	11	4	9	3	9	5	28	0	4	0	1
44	2	10	9	11	8	8	6	4	7	11	13	4	1	4	2
45	1	12	9	7	8	10	6	2	7	8	11	5	1	1	1
46	1	5	6	9	7	4	4	6	11	6	2	0	0	2	4
47	1	9	10	10	4	8	6	2	9	6	8	3	2	0	1
48	1	9	10	7	6	8	3	4	10	6	7	2	1	1	2
49	1	7	10	6	2	4	6	6	9	7	0	0	5	1	1
50	1	9	12	1	7	9	3	4	9	6	4	3	0	0	3

Figure 3.1 Selected Parameter Totals Listed by Trial Number

trial	mach	mach yell	mach gren	mach blue	mach red	sub yel	sub grn	sub blu	sub red	numb hits	num pas	hit yel	hit grn	hit blu	hit red
51	1	6	5	10	8	6	5	6	8	9	4	2	2	3	2
52	1	7	15	11	9	8	5	1	11	8	17	3	2	0	3
53	1	11	5	7	6	9	3	3	10	6	4	3	1	1	1
54	1	6	4	7	12	9	5	1	10	9	4	2	2	0	5
55	1	13	14	12	14	8	4	1	12	7	28	0	2	0	5
56	1	12	14	19	14	12	2	2	9	6	34	3	0	1	2
57	1	8	2	11	8	9	3	2	11	8	4	3	0	1	4
58	1	6	4	11	12	8	2	3	12	6	8	1	0	1	4
59	1	11	5	15	6	4	3	2	16	8	12	2	1	1	4
60	1	11	11	11	11	5	2	2	16	8	19	3	0	1	4
61	1	10	8	9	8	8	4	0	13	8	10	0	1	0	7
62	1	13	6	9	10	7	1	0	17	7	13	3	0	0	4
63	1	10	18	10	7	6	1	2	16	4	20	2	0	0	2
64	1	10	11	6	9	10	0	2	13	8	11	4	0	0	4
65	1	7	9	2	8	4	4	5	12	8	1	1	1	1	5
66	1	3	12	4	7	8	9	2	6	8	1	3	4	0	1
67	1	8	10	10	8	11	2	2	10	8	11	3	1	0	4
68	1	10	4	5	9	13	2	1	9	7	3	4	0	0	3
69	1	10	8	4	8	10	4	2	9	9	5	4	1	0	4
70	1	9	6	12	17	8	6	2	9	4	19	0	2	0	2
71	1	11	7	7	8	5	7	1	12	7	8	2	1	0	4
72	1	7	9	13	9	8	7	0	10	3	13	1	1	0	1
73	1	11	6	5	10	10	4	5	6	9	7	4	1	2	2
74	1	4	12	8	8	8	4	4	9	6	7	0	2	1	3
75	1	9	11	7	8	5	8	1	11	7	10	1	3	0	3
76	1	8	14	5	6	4	6	4	11	10	8	2	4	1	3
77	1	11	3	8	6	12	2	0	11	9	3	7	0	0	2
78	1	9	9	10	11	9	3	1	12	6	14	3	0	0	3
79	1	7	8	7	12	9	4	2	10	7	9	2	2	0	3
80	1	8	6	10	8	14	1	2	8	8	7	4	0	1	3
81	2	13	4	8	5	12	2	3	8	10	5	7	1	0	2
82	2	6	14	10	11	11	0	2	12	8	16	2	0	1	5
83	2	7	10	17	16	13	1	0	11	8	25	3	0	0	5
84	2	14	12	16	14	12	0	0	13	7	31	3	0	0	4
85	2	7	7	10	7	9	6	4	6	6	6	2	2	1	1
86	2	11	7	4	6	12	6	1	6	7	3	5	1	0	1
87	2	13	13	9	6	17	1	2	5	8	16	5	1	2	0
88	2	6	3	8	9	14	3	4	4	7	1	4	1	1	1
89	2	6	5	8	6	8	5	2	10	6	0	2	1	1	2
90	2	7	7	4	7	7	7	4	7	6	0	1	3	1	1
91	2	9	10	7	2	7	6	2	10	6	3	4	1	1	0
92	2	4	6	10	5	8	6	3	8	6	0	1	3	1	1
93	2	6	7	7	7	7	5	3	10	10	2	3	2	1	4
94	2	5	6	4	13	7	6	2	10	10	3	3	1	1	5
95	2	7	5	10	11	7	6	0	12	8	8	2	1	0	5
96	2	7	9	7	9	11	4	0	10	11	7	5	1	0	5
97	2	8	8	6	5	8	4	4	9	6	2	2	1	1	2
98	2	7	12	10	5	9	5	2	9	8	9	3	3	0	2
99	2	8	9	8	8	7	6	2	10	7	8	2	2	0	3
100	2	9	5	9	10	12	5	0	8	11	8	5	3	0	3

Figure 3.1 (Continued)

```
00310031213032110333311332
01131001110332300230333 00
22321031033101233213020 22
22033110210222333331200 0
30302202322310030330331 22
31312023001331331322130 01
22211223132332022003122 10
12211311103001322130031 20
03221123202228110100320312012310233003 1
00112231320013103300221202300013013 1
13022313010231322122130302
21112001020222311132122032110030 0
23333030020021221111031210110120
32211210012102120101001 31
11111330101033101300310231010
01202123323202222312033013130
10311212320330311102231232110221101231321 0
13310102231200200000123003322
32133133233120023230021303203
21131111030233031100300000301333133312222012221113202 2
32220232333331022012010231302232200233201313111112112200012
30021020322232132003022203323
12232300332133221200130330223323 2
02220033020232120231232030100222212 01
22121100300031311303030212303222031112021323
03221320000232112031322130301030211
10110332022100001033330021020223232303
03311102230200001211231122311121123311010012 1
02031113102110130103312200123332010 3
13133011310013013133020102
10103132133321232111110113
33020110201203213123121221003220311 3
12302000020332103100312033 33
10113003220133130033030102012 1
30132032333032330033012022323213303123021212
11223302200120030903100012312103 3
13221230023032101331321221230112202203
10122031320033013313300100200233
33120221109320211133311121122013
31022132112201313120103131103033000
23101111223201111103100031120130 3
00002233023020023210002331 12
30231032132333112102013120001023213022 3
33130113132013033101232103200332 22
```


Figure 3.2 Color states of machine 1 during the experiment (0-yellow, 1 green, 2 blue, 3 red)

Figure 3.3 Color states of machine 2 during the experiment
(0 yellow, 1 green, 2 blue, 3 red)

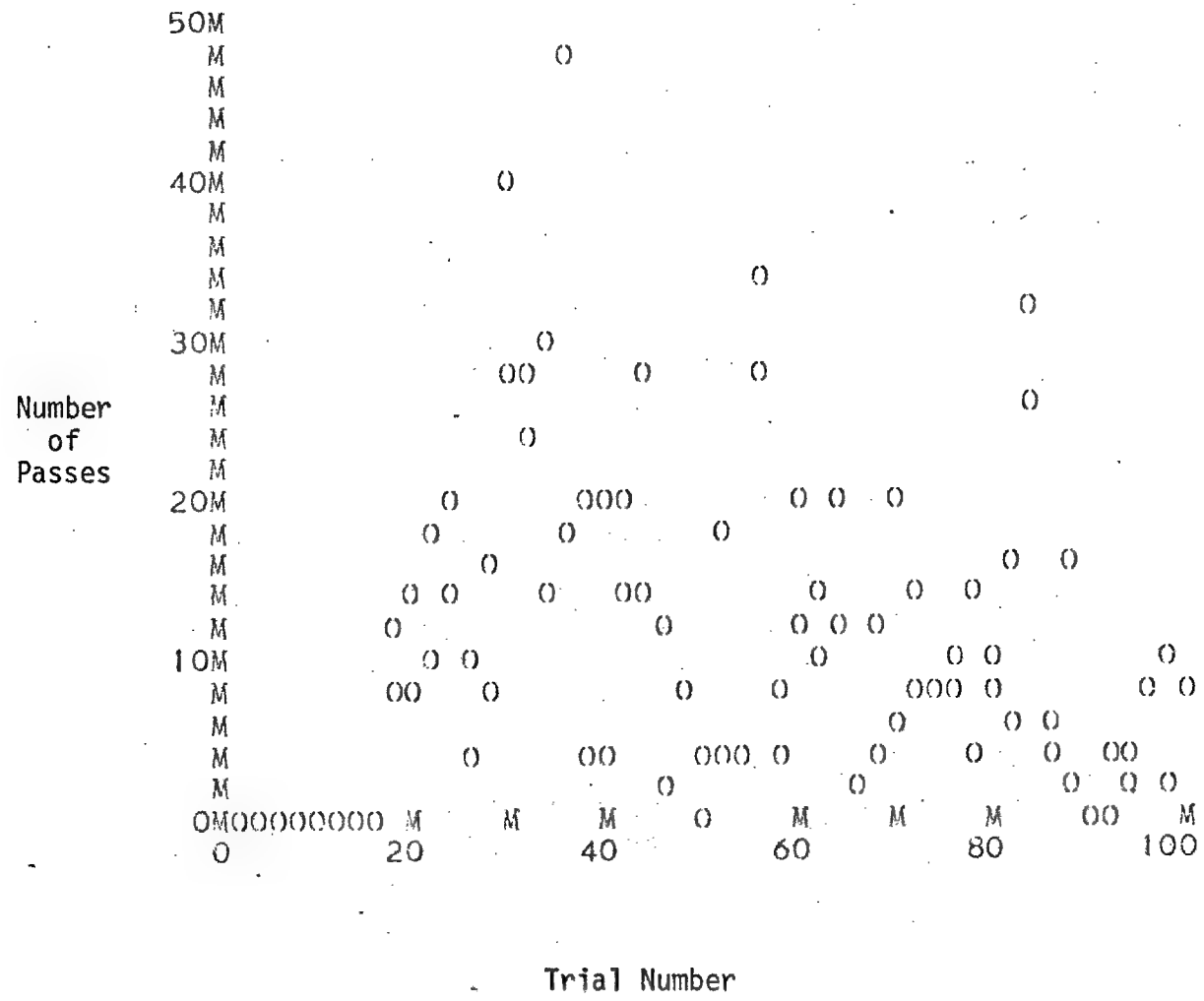


Figure 3.4 Total number of passes summed over a trial

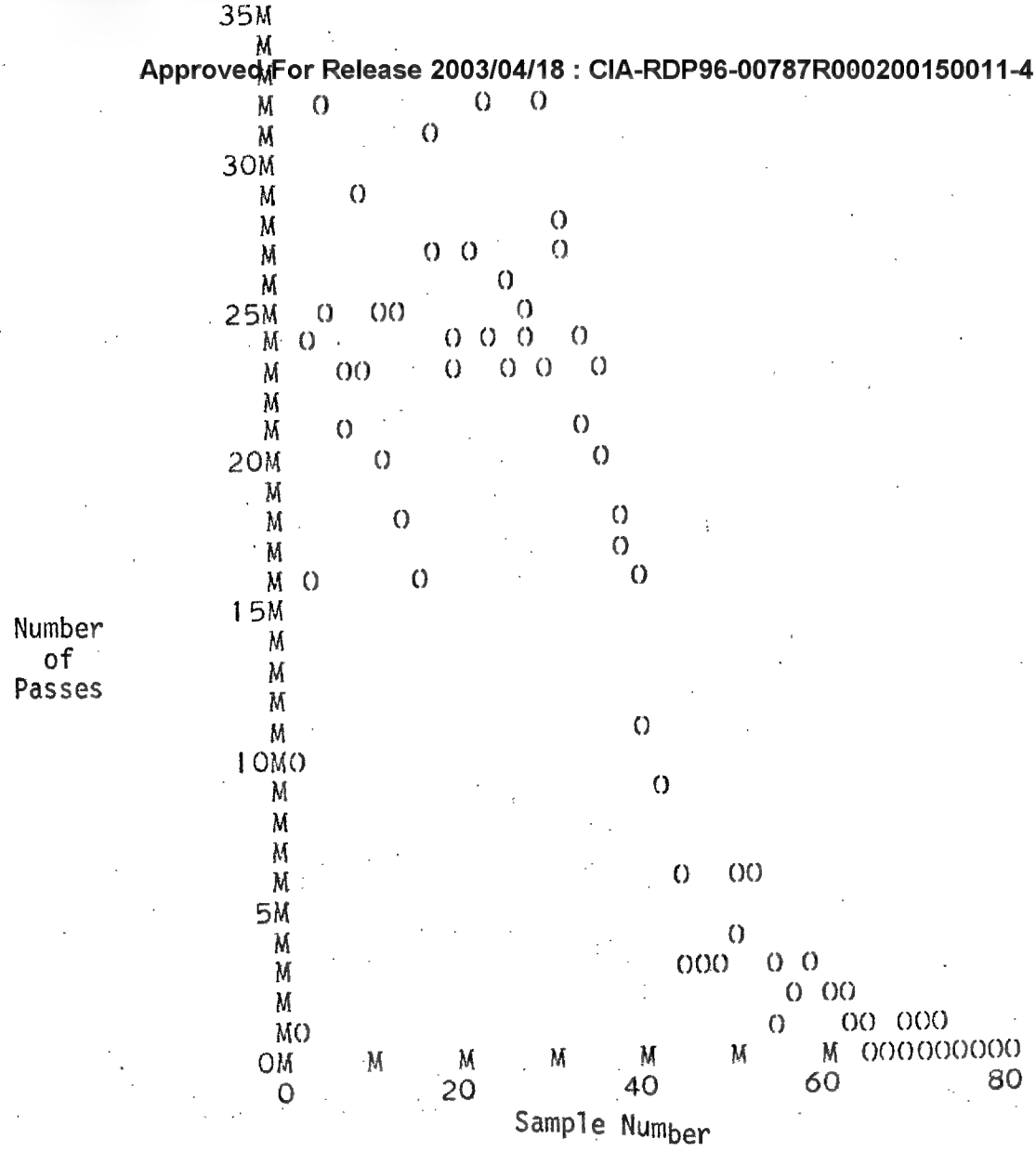


Figure 3.5 Total number of passes summed over sample number

C. Number of passes and the number of hits vs. the trail number on one plot. Investigation of the hits/passes relationship was dropped when the coefficient of correlation between the two was computed at -.114

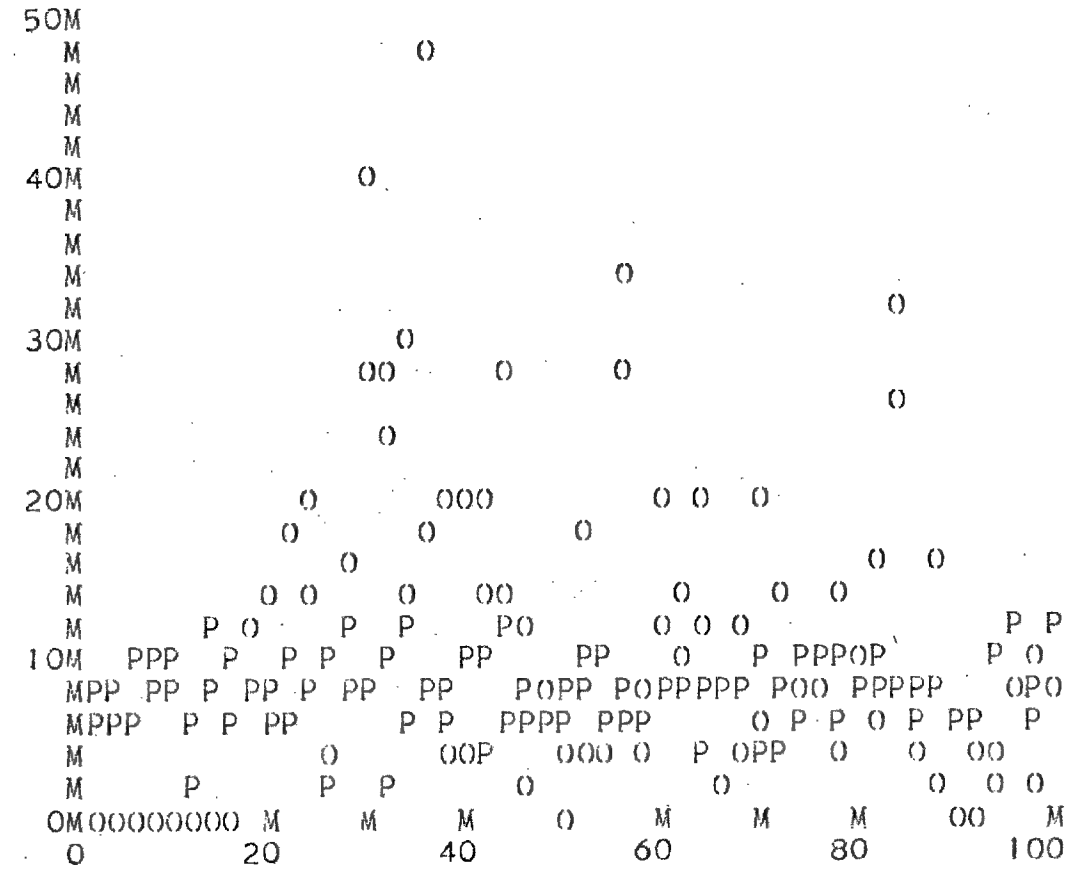


Figure 3.6 Plot of number of hits per trial and number of passes per trial

IV. Tables of state transitions which reflect the influence of the subject on the machine. For color choices of the subject the table shows the number of colors the machine has on the next sample. For example on the first table, when the subject picked yellow, on the next sample 197 times the machine state was yellow.

	MACHINE STATES ON FOLLOWING SAMPLE				
	Yellow	Green	Blue	Red	
Yellow	88	77	87	95	
Green	38	46	39	47	Machine 1
Blue	27	28	24	24	
Red	120	105	99	112	
Pass	84	83	98	81	
Yellow	109	124	128	141	
Green	58	47	58	66	Machine 2
Blue	25	32	42	30	
Red	121	125	136	102	
Pass	146	162	161	168	
Yellow	197	201	215	236	
Green	96	93	97	113	Both Machines
Blue	52	60	66	54	
Red	241	230	235	214	
Pass	230	245	259	249	

Figure 3.7 State Transitions from Subject Choice to Future Machine State

V. Because of the possibility that the subject was learning the state of machine 2 the distribution of the colors are plotted in Figures 3.8, 3.9, 4.0, and 4.1. The only states used are those in which the subject didn't pass. Therefore there is a total of 25 for each trial.

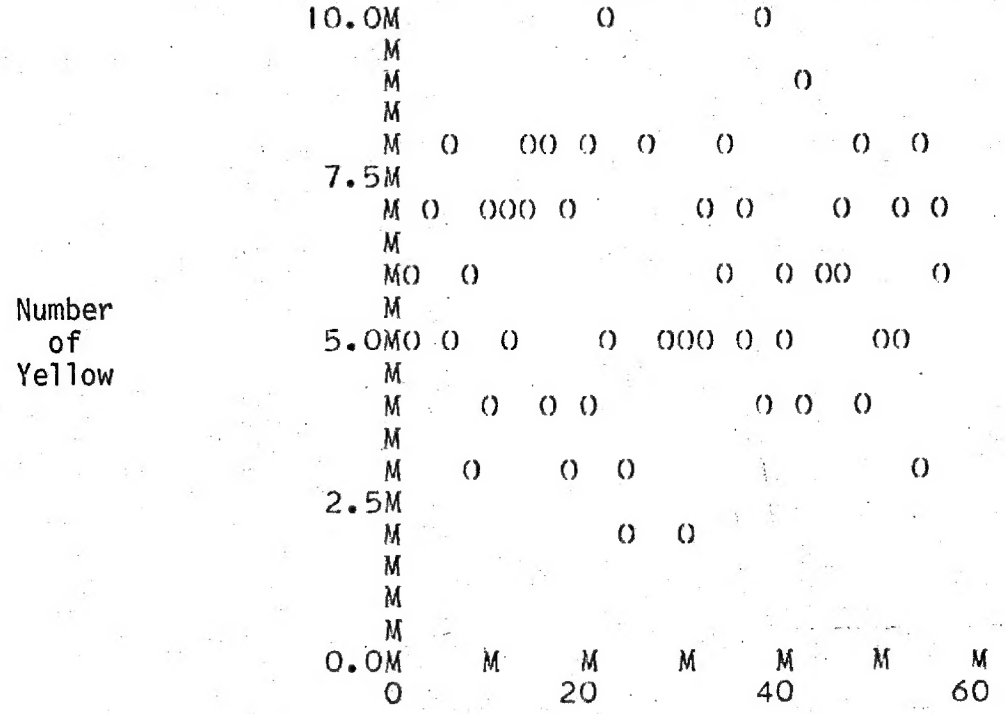


Figure 3.8 Distribution of Yellow for Machine 2

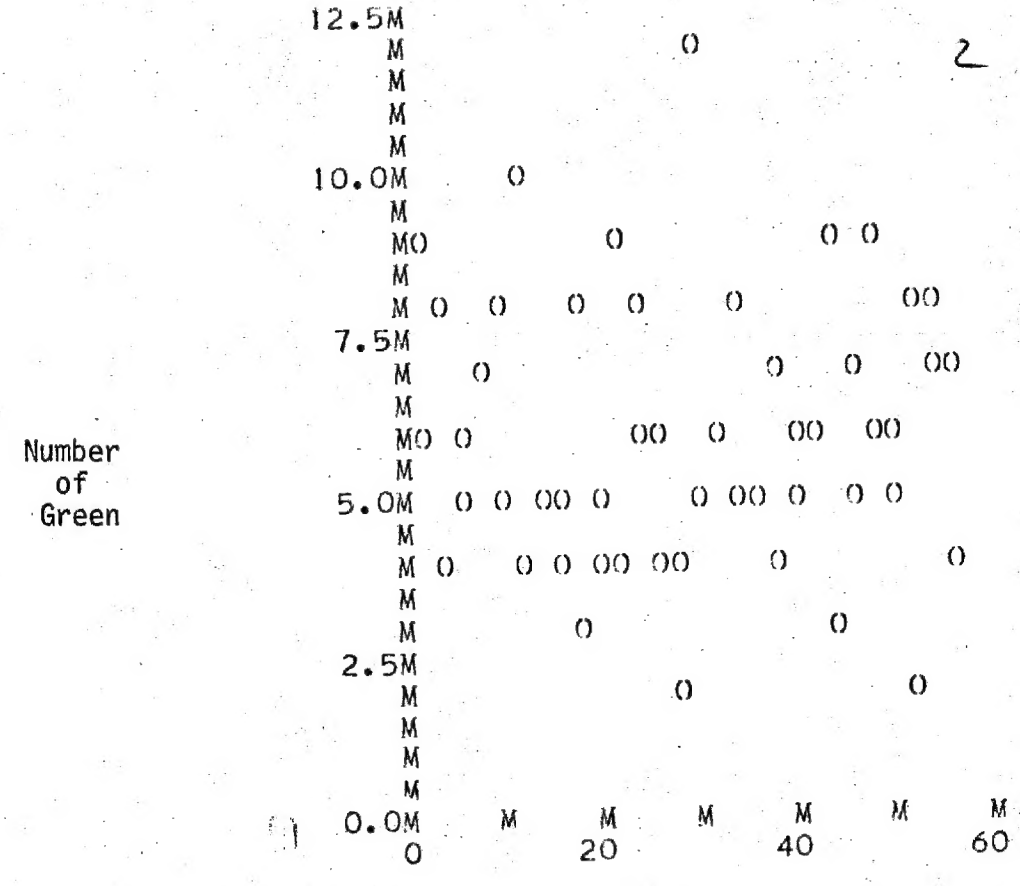


Figure 3.9 Distribution of Green for Machine 2

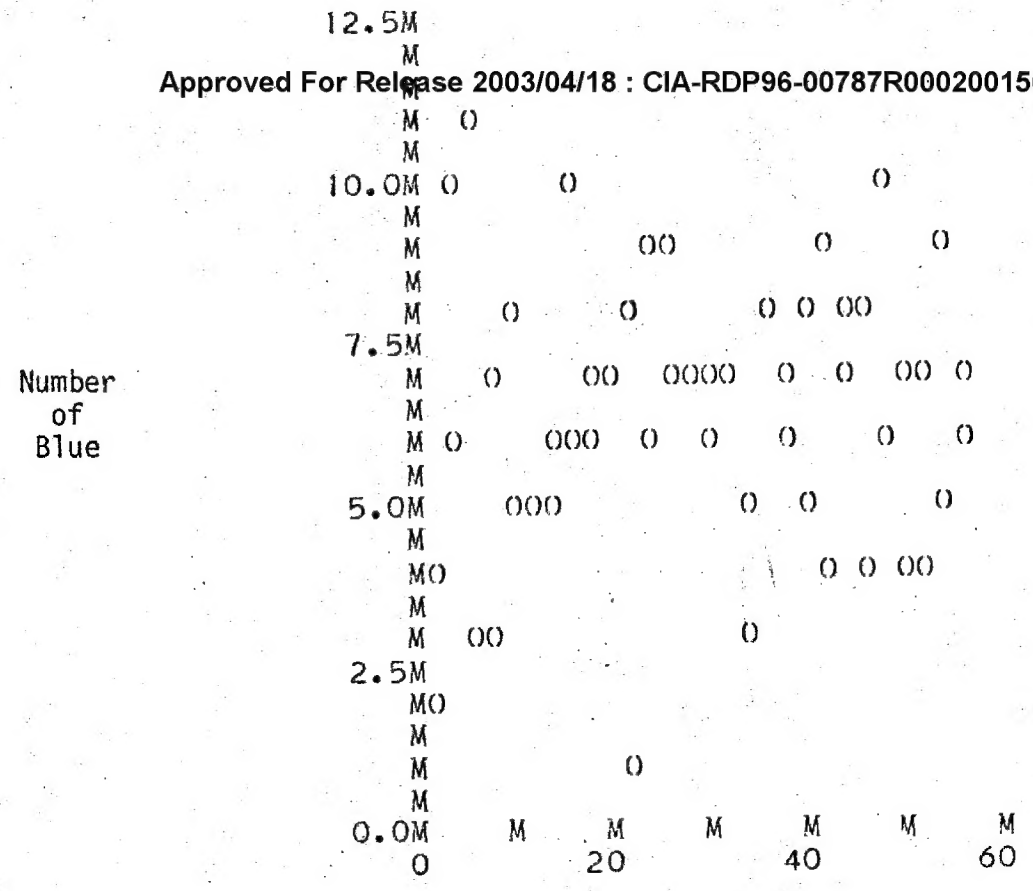


Figure 4.0 Distribution of Blue for Machine 2

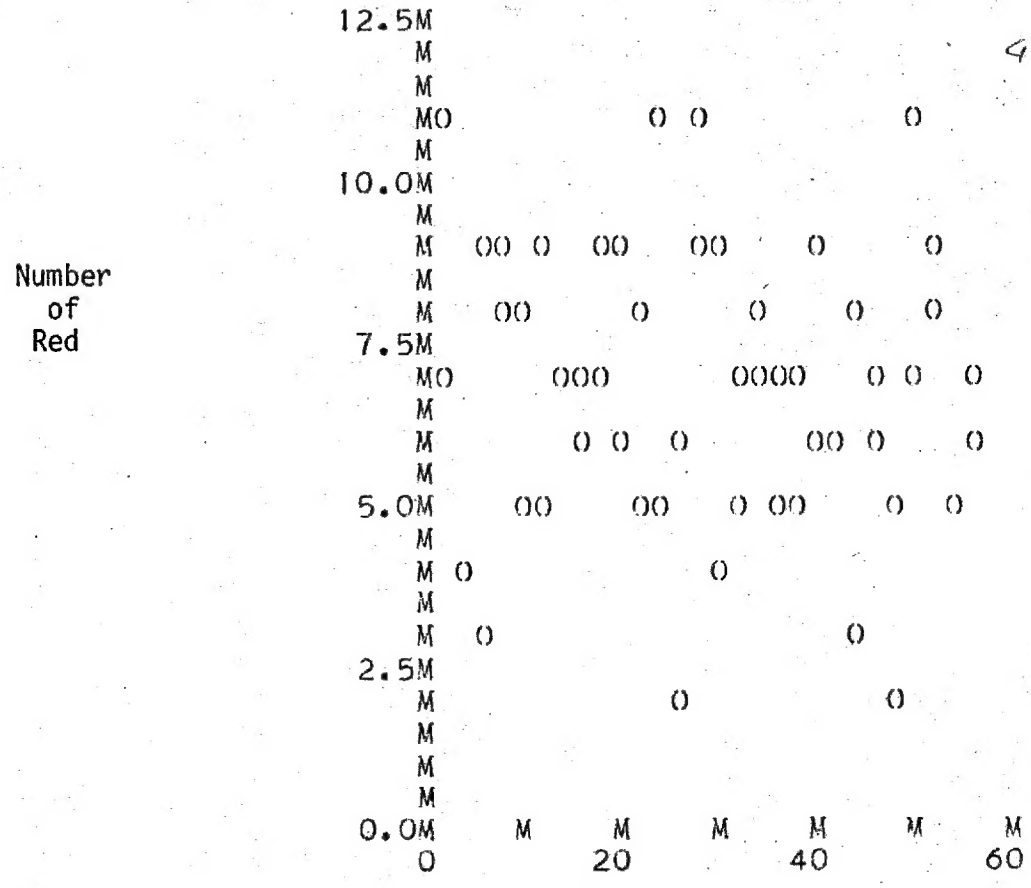


Figure 4.1 Distribution of Red for Machine 2

Test	Description	Scoring					
		S1	S2	S3	S4	S5	S6
Halstead Category Test	Nonverbal test requiring abstraction of conceptual relationships. Score: Total errors.	7	14	33	26	6	28
Tactual Performance Test	Requires placement of 10 geometrically shaped blocks in their correct locations on a formboard while blindfolded. Separate RT, LT, and bimanual trials. Score: Total time (min.).	16.4	11.8	7.7	7.7	11.4	6.9
Speech Perception Test	Discrimination of non-word speech sounds. Score: Total errors.	4	2	0	2	5	3
Seashore Rhythm Test	Discrimination of nonverbal rhythms. Score: Number correct.	27	25	28	29	26	29
Finger Tapping Test	Measure of finger oscillation rate for 10-sec. period, both RT and LT hand trials. Score: No. taps/10 sec.	RT/LT 53/50	RT/LT 53/49	RT/LT 48/47	RT/LT 54/53	RT/LT 47/47	RT/LT 48/43
Trail Making Test (Part A)	Requires connecting numbered circles in order from 1 to 25. Paper and pencil task. Score: Total times (sec)	40	16	18	19	30	27
Trail Making Test (Part B)	Requires connecting alphabetic and numbered circles by alternating 1→A→2→B, etc. Score: Total time (sec)	56	50	55	50	54	53
Knox Cube Test	Measure of attention span and immediate visual memory. Score: Number correct.	13	14	13	16	17	17
Raven Progressive Matrices	Nonverbal intelligence test involving spatial matrices. Score: Number correct.	39	53	49	55	60	54
Verbal Concept Attainment Test	Requires abstraction of verbal conceptual relationships. Score: Number correct.	22	24	27	23	21	24
Buschke Memory Test	Requires learning a 20-word list in a maximum of 12 trials with repetition of words omitted after each trial. Score: Max. no. words correctly remembered; List: no. words consistently remembered	Total: 14/20 List: 8/20	17/20 14/20	18/20 11/20	19/20 16/20	20/20 15/20 (8 trials)	20/20 16/20 (7 trials)
Grooved Pegboard Test	Requires insertion of 25 pegs in their holes in a pegboard. Both RT and LT hand trials. Score: Total time (sec).	RT/LT 76/74	RT/LT 69/70	RT/LT 58/67	RT/LT 59/67	RT/LT ~~79/88~~ 72/70	RT/LT 48/50
Spatial Relations Subtest of the PMA	Requires mental rotation and identification of figures rotated in 2 dimensions. Score: no. correct - no. errors.	-	-	-	-	60	52
Gottschaldt Hidden Figures Test	Requires tracing outline of simple figure hidden within lines of more complex figures. Score: time and no. correct.	Poor	Avg.	-	v.good	outst.	outst.